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ANALYZING HSS (HIGH SPEED STABILITY) RESULTS

Effectivity:

Parts of this Service Note are related to the newer systems that have UCERD and the 1.5T RF/PDU. However, most of methodology explained within can be applied to any Lx System.

Problem:

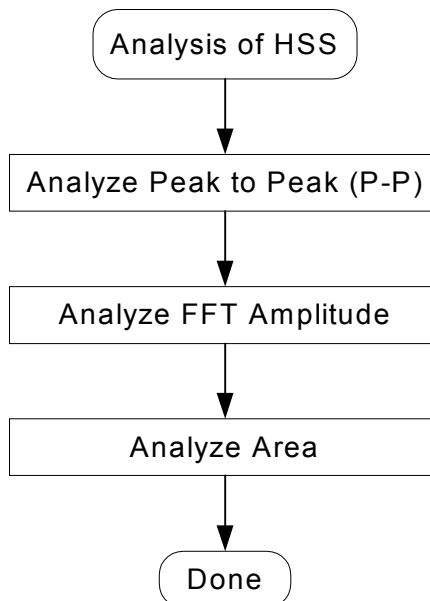
HSS Area has been failing specification since the introduction of 2 new hardware components approximately December 1999. The current specification for Area is < 1.2 counts.

The UCERD (Universal Combined Exciter Receiver and Data Acquisition board) was developed and phased into production so that a single Exciter/Receiver configuration could be used at different field strengths. However, this also introduced low level phase noise that is characterized as broadband noise and higher Area in HSS.

Approximately the same time, the 1.5T RF/PDU was also phased-in. The 1.5T RF/PDU Test port, which is used to supply RF energy to the HSS Coil, no longer utilized a blanking signal. The previous generation RF Cabinet used a blanking signal to force the output to a zero state between RF pulses. Without this blanking signal, any noise created by the RFI circuitry would show up as additional broadband noise. Again, this broadband noise would be identified as higher Area in HSS.

The HSS fault isolation process described in this Service Note is to help analyze HSS Frequency Stability Test results and provide the correct flow to troubleshooting and fault isolation. **Do not** arbitrarily diagnose failing FFT Area results as a function of the UCERD or the 1.5T RF/PDU.

HSS Fault Isolation Process:



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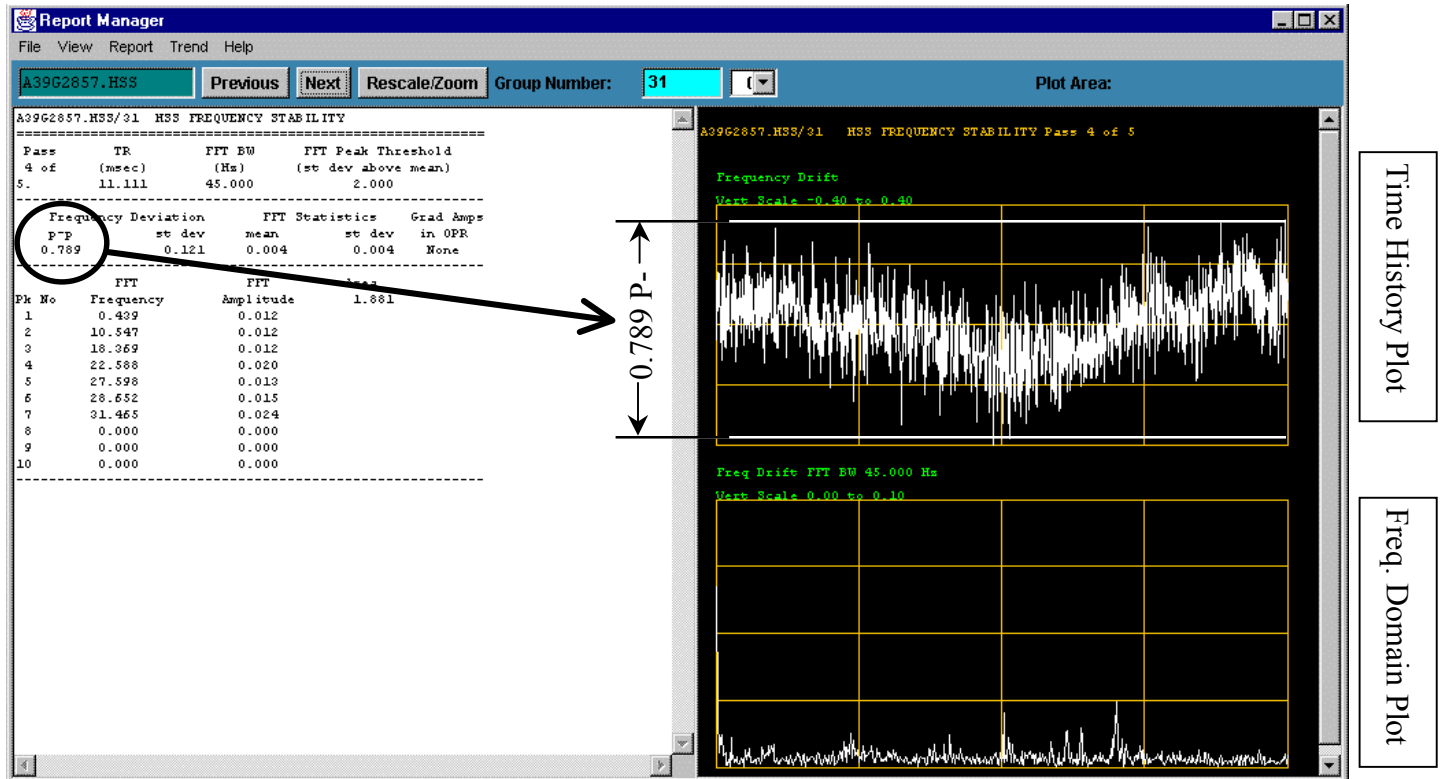
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Peak To Peak (P-P) Analysis

The time history plots display the real time frequency drift collected during the scan. Each scan is comprised of 5 passes, each pass is plotted on its own page along with its corresponding frequency domain plot (post FFT) below it.



FAILING P-P SPEC.
ILLUSTRATION 1

Review the time history plots. Review each of the 5 individual passes for P-P Frequency Deviation. The maximum allowed frequency instability specification is **0.7 P-P** within a 40cm Diameter Spherical Volume (DSV).

The Time History plots should show a signal with a frequency component that is fairly centered and horizontal on the graph. There should be no upward or downward slope. Abnormalities are displayed as transient bursts, frequency patterns, sloping curves, or low frequency curves (See Illustration 1).

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In Mobile environments, windy days can cause van movement which will affect frequency drift. An indication in the plot of van motion due to wind typically results in a very low frequency "wave" in the time history plot and a large slope decay from 0 to 1-2 Hz range in the FFT plot. If wind is suspect, rerun HSS after changing **CV rhuser5** from 0 to 1. This selects a Hanning filter that removes very low frequencies. HSS would now produce twice as many plots (with and without the filter).

See Hanning Window Section in this document. See examples of Van motion caused by wind in the Hanning Window section, Illustration 11 on page 16.

Also, movement of the van, such as a person walking can cause P-P failures as well as Area and FFT amplitude failures.

Movement in a van or movement around the magnet during HSS will typically cause failures and the test will need to be rerun!

Unstable magnet pressure will also cause Frequency drift. If the magnet was just refilled with Helium, the Chiller was off, or there is a significant Scan room temperature change, frequency drift can occur. Recheck Center Frequency during Manual Prescan. If it is changing, let the system stabilize or troubleshoot the center frequency drift problem.

The Magnet Monitor would also indicate changing Helium pressure.

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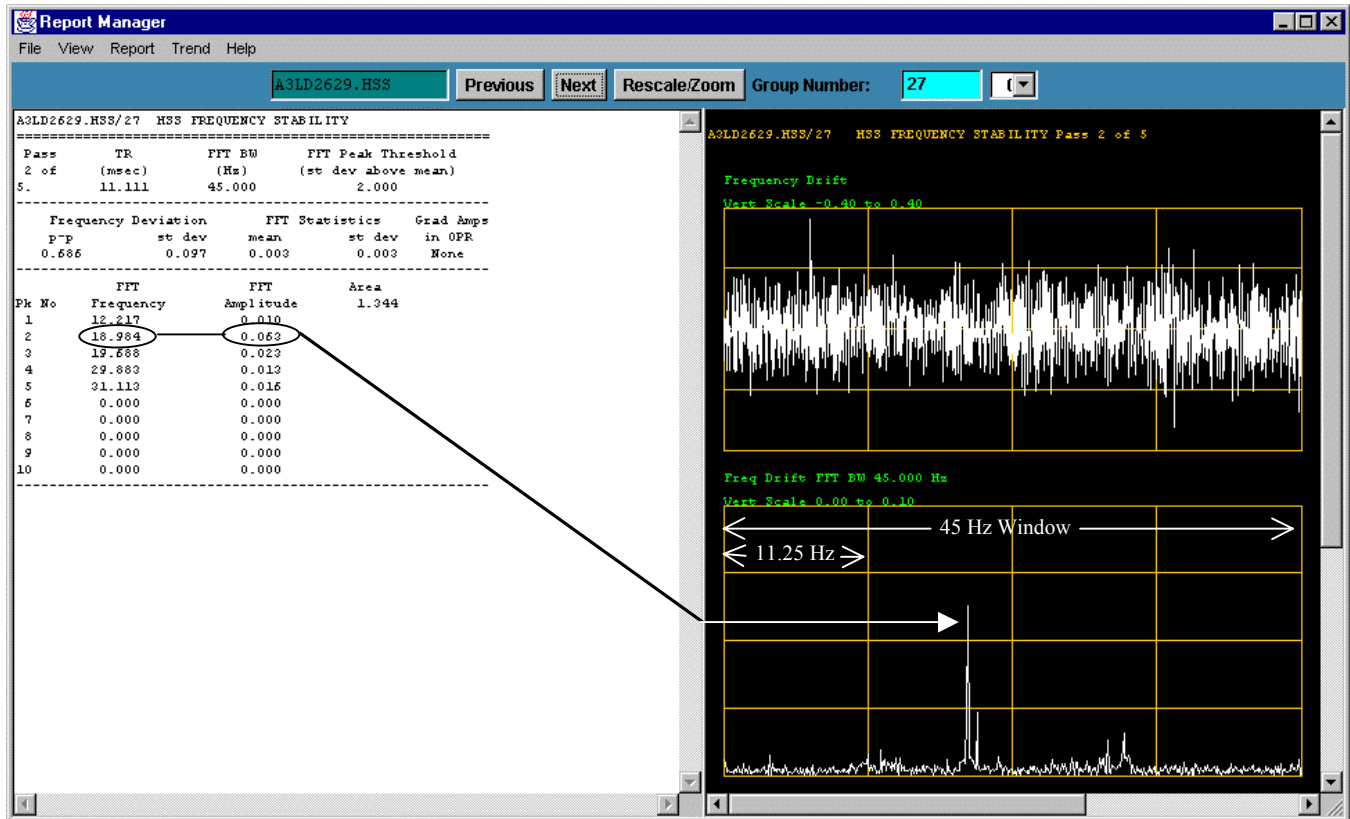
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FFT Amplitude

When analyzing HSS for high spikes in the FFT plots, view each of the Frequency Domain (FFT) plots to see if the spike is consistent across all 5 passes or is intermittent.



FFT AMPLITUDE SPIKES
ILLUSTRATION 2

The FFT amplitude is an indication of the magnitude/strength of the vibration, or noise at a particular frequency. ILLUSTRATION 2 shows the plot a HVAC fan that is slightly out of balance causing a spike on the FFT graph at a frequency of 18.984 Hz, and with an amplitude of .063 (e.g. ILLUSTRATION 2). A fan that is extremely out of balance could have the same frequency component of 18.984Hz, but the FFT amplitude (spike height) could be 0.1 counts or higher. The higher the spike or FFT amplitude, the greater the amount of area under the spike, causing higher Area, which also may fail spec. **Fix the cause of the spike first, before attempting to fix high Area.**

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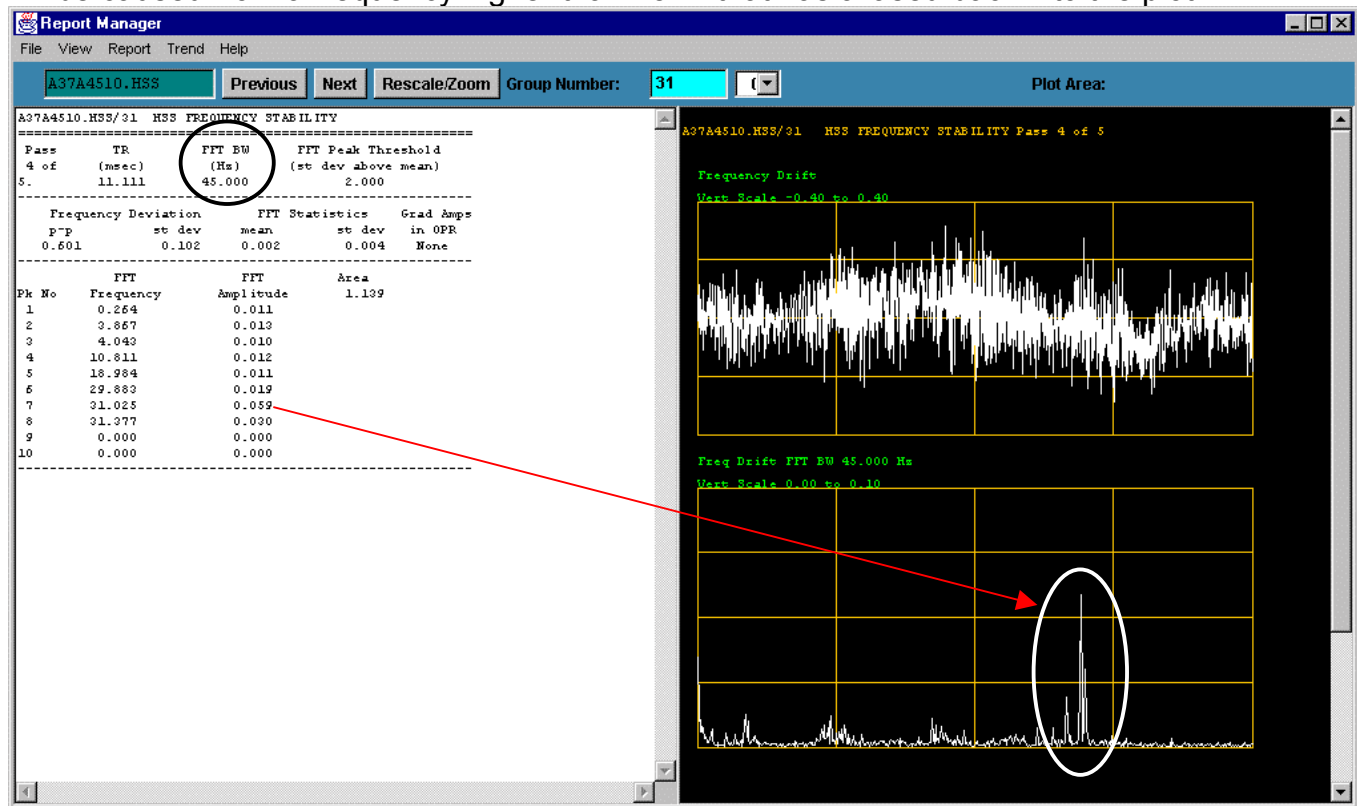
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FFT Amplitude not within spec:

Identify the frequency associated with the high amplitude peak. Since HSS only reports frequencies up to 45Hz (while in the low bandwidth mode using the 0.25 NiCl₂ sample), frequencies above 45Hz can be “aliased” back into the 0 – 45Hz plot and be mis-represented as a different frequency.

To make sure that you are troubleshooting the correct frequency, follow these steps:

- 1) Perform an HSS scan and analysis in the normal mode. Record output file number.
- 2) Using Report Manager, review the Time History plots, not the averaged plot. The example plot (ILLUSTRATION 3) indicates a high “spike” at 31.025Hz with a FFT amplitude of 0.059. Even though the amplitude is within spec (less than 0.1), it is still unusual. The question to be answered, is 31.025Hz the real frequency, or could this spike be caused from a frequency higher than 45Hz that has aliased back into the plot?



FFT BW = 45HZ
ILLUSTRATION 3

- 3) Verify the frequency of the “spike”. It is important to know the correct frequency which will help in troubleshooting (i.e. knowing the actual frequency to compare with accelerometer results, or by determining the RPMs to find corresponding rotational frequencies of fans, blowers, motors, etc.).

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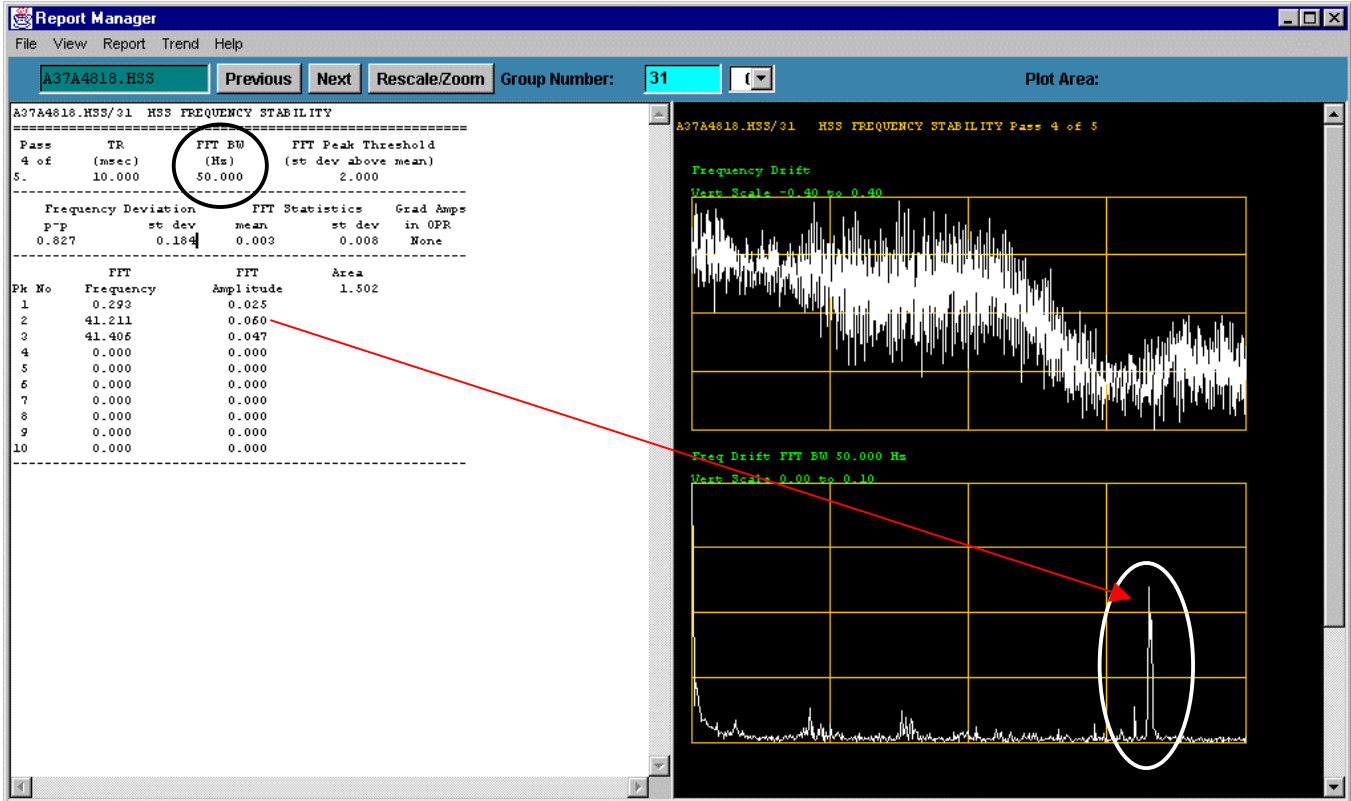
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7) Display the Time History Plots using Report Manager. See ILLUSTRATION 4, FFT BW = 50Hz.



FFT BW = 50HZ
ILLUSTRATION 4

8) Determine if the spike moved.

- If the spike appears to have moved slightly to the left, and is reporting a similar FFT Frequency, then the correct natural frequency value has been reported.
- If the spike has moved to the right, and the reported frequency is higher, then the spike is caused by a higher frequency that has aliased back into the 45Hz bandwidth. To determine the actual higher frequency value:
 - Find the difference between the reported frequency of the 50Hz and the 45Hz bandwidth scans.
 - Add the difference with 45Hz. (See example on following page.)

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Using the Example from ILLUSTRATION 3:

- Spike is at 31.025 Hz in the 45Hz BW scan.
- Expanding the Bandwidth to 50Hz, the spike moves to the right and is now reported as 41.211Hz (see Figure 4). *This indicates that the natural frequency is above the 45Hz window.*

Find the Frequency:

- $45\text{Hz} - 31\text{Hz} = 14\text{Hz}$ Difference between Reported Freq. and Bandwidth.
- $45\text{Hz} + 14\text{Hz} = \underline{59\text{Hz}}$ Actual Frequency of the disturbance.

It also works using the 50Hz Bandwidth plot:

$50\text{Hz} - 41\text{Hz} = 9\text{Hz}$ Difference between Reported Freq. and Bandwidth.

$50\text{Hz} + 9\text{Hz} = \underline{59\text{Hz}}$ Actual Frequency of the disturbance.

10.) Troubleshoot and find root cause of component that is vibrating at 59Hz.

Additional Troubleshooting Tips:

Spikes that are very narrow (e.g. 1 pixel in width) are usually caused by electrical sources. Mechanical vibrations typically cause spikes that have some bandwidth (like the previous examples) or spikes that vary in frequency, even slightly.

Check frequency with **Table 1** to see if it is a known system or mobile component that may be suspect. (This table is a guideline and **should NOT** be used to identify a source as a definitive problem.)

Turn off a component and see if the peak at the offending frequency is removed or greatly reduced.

If YES, troubleshoot the component to find root cause.

If NO, continue turning off components one at a time and take an HSS scan to determine if frequency spike is gone.

Turn OFF components in the following order:

1. HVAC (Heating, Ventilation and Air Conditioning), including blowers in Mobile environments
2. Gradient Patient Blower
3. Heat Exchanger
4. Chiller
5. Other

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Other Observations:

Narrow Spikes: If the spike is very narrow (e.g. 1 pixel in width) from the base to the top, and the frequency is consistent with every HSS scan, then the spike may be caused from an electrical source. For example, the 29.833Hz spike seen on systems with a UCERD, is caused by a 60Hz harmonic feedback from the UCERD. This is a known pattern for a UCERD and the amplitude is usually small in normal situations. (See ILLUSTRATION 3, Pk No 5 (peak number 5).)

Wide Spikes: If there is some bandwidth to the spike and/or the frequency drifts slightly from one scan to another, then the spike is usually mechanical in nature. (See ILLUSTRATION 4, Pk No 2.) Check for mechanical vibrations from various components. See Table 1.

TABLE 1
FREQUENCY VS. SUSPECT CAUSES

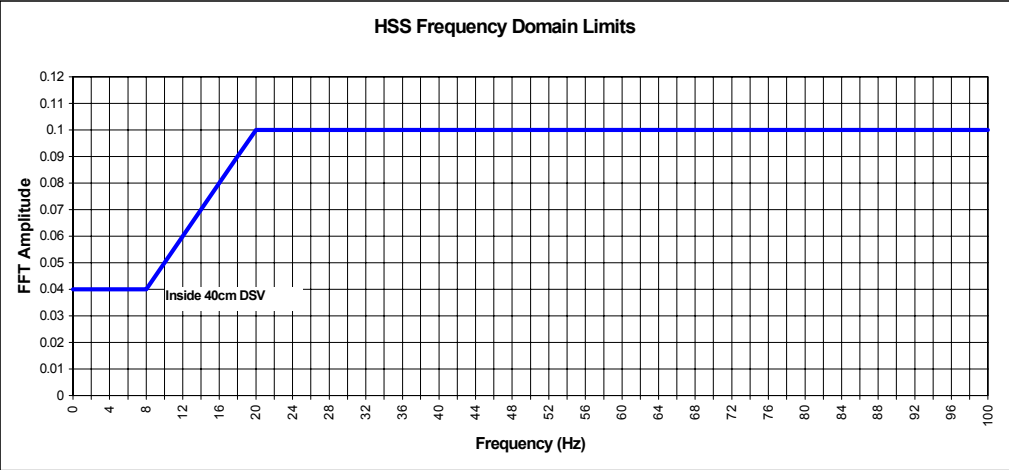
Frequency	Suspect Component
< 1Hz	Could indicate siting or magnet problems.
1.2 Hz	Cold Head
3-10Hz	Natural frequency of van, may be enhanced by van motion caused by wind, etc.
11Hz	Resonance Freq. of Ellis & Watts mobile
~11.25Hz	Compressor belt on Ellis & Watts mobile
~18 –19Hz	HVAC system
23 Hz	Chiller Blower
29.883Hz	60Hz noise/harmonic on UCERD, OK if not excessively high.
~30-34Hz	Magnet mounting not shimmed or loose.
~20- 40Hz	60Hz Electrical noise
~59 – 60HZ	HVAC compressor vibration

Converting frequency to RPMs

To identify the rotational frequency or Revolutions Per Minute (RPM) of equipment such as fans or blowers, multiply the reported FFT Frequency by 60. For example, a peak located at 19Hz multiplied by 60 is equal to 1140 RPM. This happens to be the number of revolutions per minute of the fan blades in the HVAC (Heating Ventilation and Air Conditioning) on Mobiles. An HVAC service person would be required to balance the fan or to replace/repair the fan vibration isolation, if it demonstrated that it causes image quality problems.

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The Spec for the Amplitude of a peak value is dependent upon frequency using the following Chart:



HSS FREQUENCY DOMAIN SPECS.
ILLUSTRATION 5

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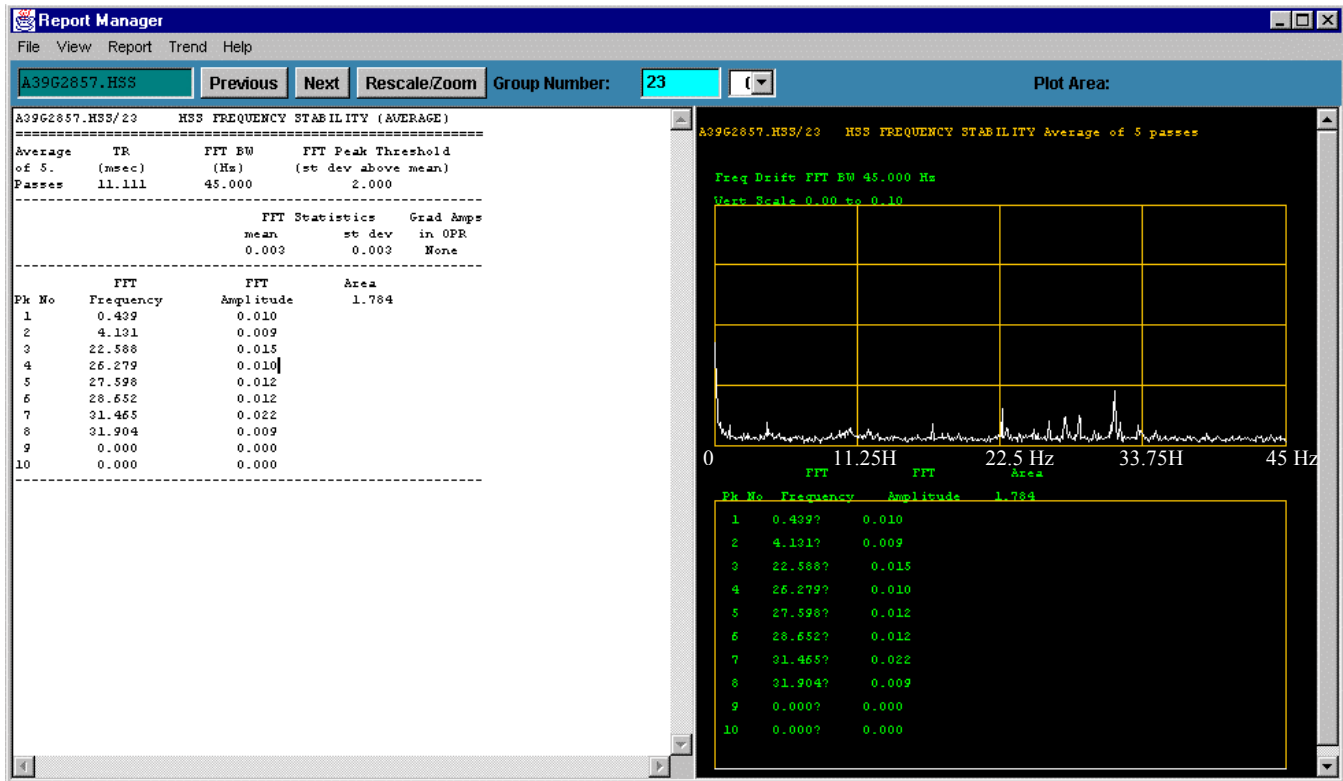
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FFT Area Analysis

The first Plot shows the average of all 5 HSS scans.



AVERAGE OF 5 PASSES
ILLUSTRATION 6

The Area is a measurement of the amount of “space” under the FFT Plot line. Since HSS analyzes frequency components between 0 to 45 Hz, higher area across the entire graph indicates presence of broadband noise. This is only true IF there are no significant “Spikes” or larger bandwidth “mounds” present in the plot.

Example of a relatively good HSS plot with elevated Area is shown in ILLUSTRATION 6. This graph shows a relatively flat plot with few, low spikes, however the Area is calculated to be 1.784 which is above Area spec (1.2). *Note the elevated baseline (e.g. the baseline is not at zero).*

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The example in ILLUSTRATION 6 clearly shows the effect of broadband noise. To reduce the broadband noise, the following must be used when executing HSS tests to meet the HSS Area specification:

- Revision 8.3 M5 (or later) System Software (Has revised PSD to compensate for UCERD Phase noise) and,
- Alternative method using the signal from the Head Port through an attenuator (to compensate for noise coming from the RFI). See ILLUSTRATION 7.

If the broadband noise is still present (>1.2 cts.), then further troubleshooting is required to determine the source of the noise.

Troubleshooting Tips:

Evaluate each of the 5 individual passes from the HSS scan. Before troubleshooting failing Area, verify Peak to Peak and FFT Amplitude are within specifications on all scans. Elevated Area caused by broadband noise will be present in all 5 scans and should be relatively flat (e.g. No humps or spikes). If high Area, spikes, or humps are intermittent, look for components which cycle power (turn off and on) as a possible suspect, for example, HVAC.

Turn off components one at a time and take a HSS scan to isolate the root cause by process of elimination. It may be necessary to look outside of the scan room as elevators, hospital generators, HVAC, nearby construction, or traffic could also induce vibrations. If this is the case, you may have to contact the OnLine Center or Local Support Engineer (e.g. ZSE or RSE) to assist in troubleshooting and/or contacting a vibration expert or consultant.

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HSS Test using the Head Output Port Procedure

1. Hardware Configuration



HSS USING HEAD OUTPUT CONFIGURATION
ILLUSTRATION 7

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2. Software / Scan Configuration Setup

Set up for the HSS scan per the normal directions. The exception is the RF Amp setup.

1. Enter the HSS prescription per the normal directions
2. After the prescription has been saved and downloaded, modify CV **rfamp_type = 2**



Default = 0

MODIFYING CONTROL VARIABLES ILLUSTRATION 8

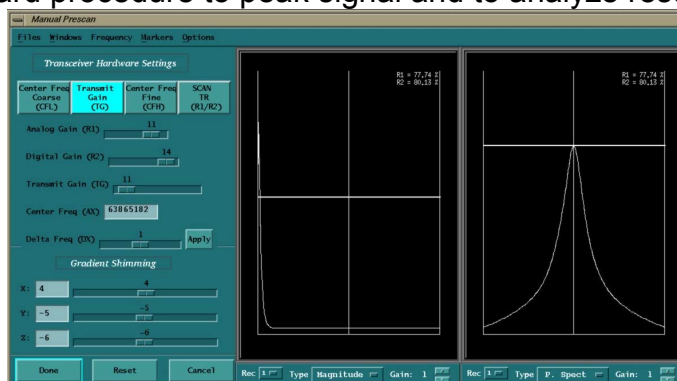
3. Download and go into Manual Prescan.

Note

If you get DD or TR Driver errors, check the attenuator setups.

If you do not get any signal, exit Manual Prescan and go back into modify CV's.

4. Follow standard procedure to peak signal and to analyze results.



MANUAL PRESCAN ILLUSTRATION 9

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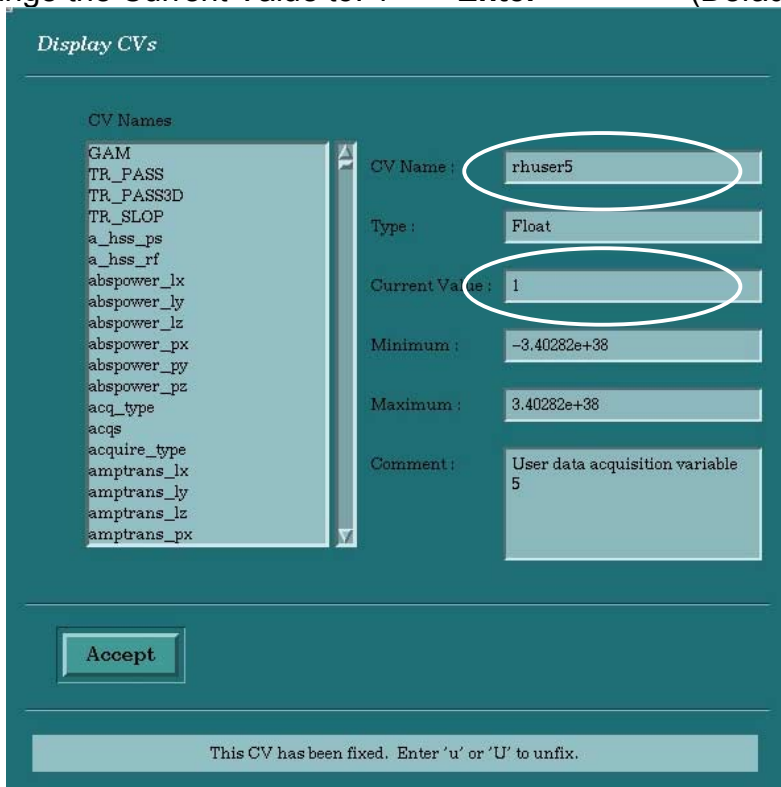
Hanning Window Filter

The use of this filter basically removes low frequencies, in the range of approximately 0 – 2 Hz and the corresponding Area calculations reflect this change. This option is primarily used in alternate environments (e.g. Mobiles) where wind can cause low frequency “rocking/movement” of the van **AND** other System related components have been ruled out as the cause of the low frequency oscillations (e.g. the coldhead). The use of this filter option may remove “Real” low frequency disturbances and cause further confusion during troubleshooting. Always evaluate both Unfiltered and Filtered plots to determine wind-related motion or possible “Real” System related problems (See ILLUSTRATIONS 12 & 13).

The Filter must be enabled prior to the HSS Scan. The filter cannot be applied to an existing HSS file.

With the System set-up for an HSS scan, change CV **rhuser5** value from “0” to “1”.

- From **Research Operations**,
- Select **Display CV's**
- For CV Name, type or select: **rhuser5**
- Change the Current Value to: 1 **<Enter>** (Default value is 0)



Display CVs

CV Names

GAM
TR_PASS
TR_PASS3D
TR_SLOP
a_hss_ps
a_hss_rf
abspower_lx
abspower_ly
abspower_lz
abspower_px
abspower_py
abspower_pz
acq_type
acqs
acquire_type
amptrans_lx
amptrans_ly
amptrans_lz
amptrans_px

CV Name : rhuser5

Type : Float

Current Value : 1

Minimum : -3.40282e+38

Maximum : 3.40282e+38

Comment : User data acquisition variable
5

Accept

This CV has been fixed. Enter 'u' or 'U' to unfix.

Note

As with all CV changes, you must always remember to:

From Research Options

- Select Download

HANNING WINDOW CV
ILLUSTRATION 10

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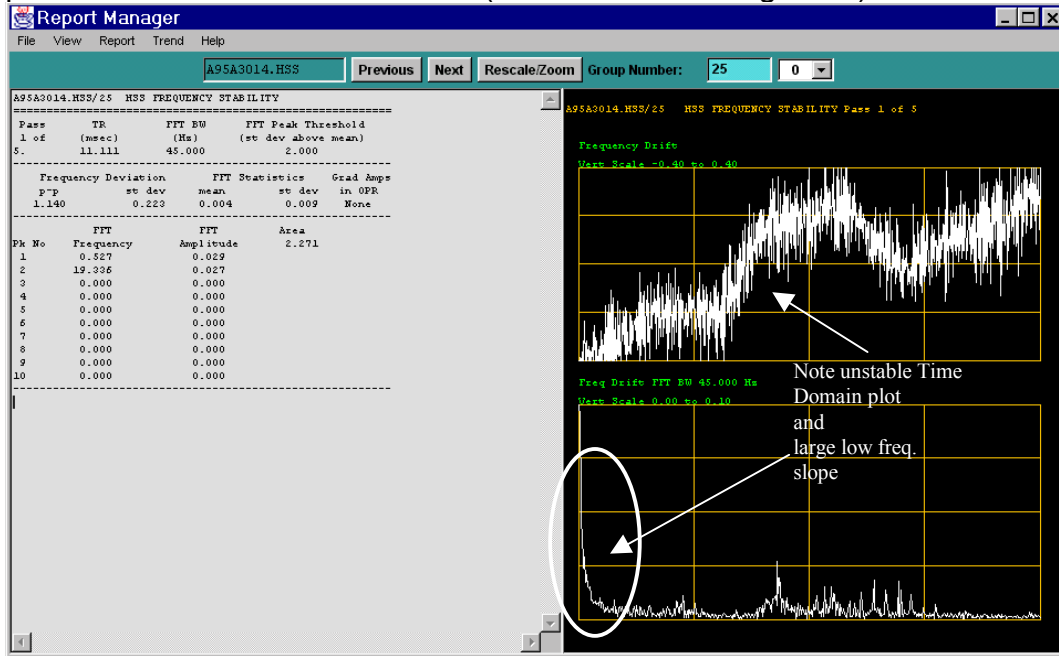
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The HSS plots will show BOTH the Normal (without the Hanning Filter) and the Filtered Plots.



STANDARD, UN-FILTERED PLOTS
ILLUSTRATION 11

If strong winds are present and the HSS plot indicates a intermittent high P-P signal in the Time History plots AND the Amplitude plots indicates a slope from 0 – 2 Hertz with a “Hump” near 3- 4 Hz and 10-11 Hz (which indicates van rocking, as seen in ILLUSTRATION 11), then it may be appropriate to use the Hanning Filter. Otherwise, use of the Hanning Filter may mask other System or Van related problems.

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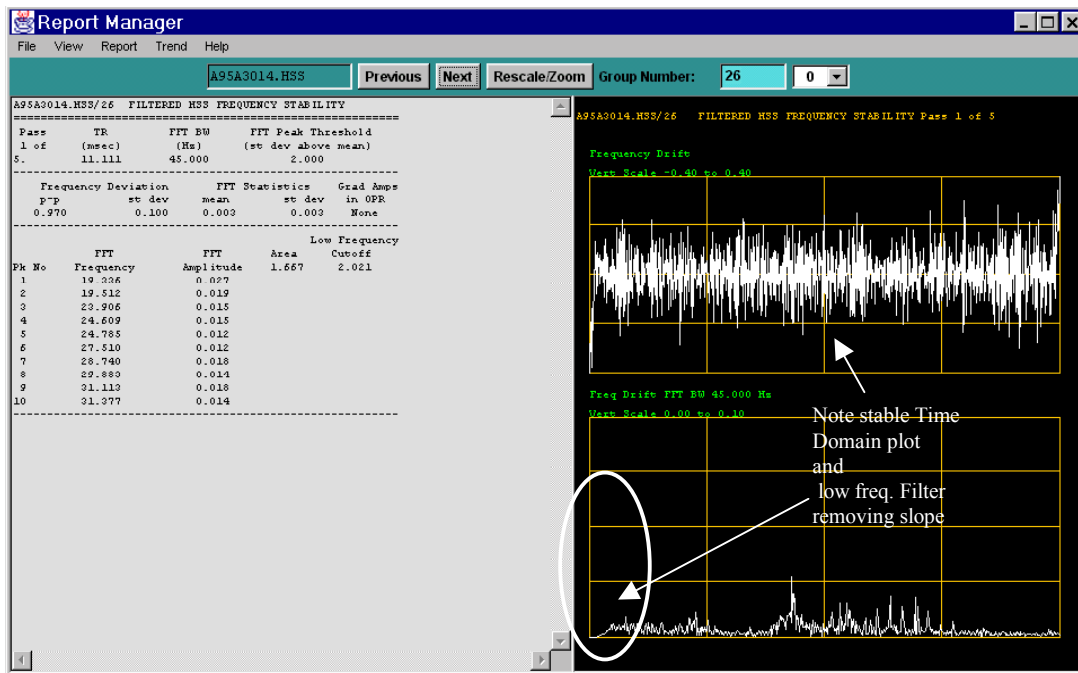
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HANNING FILTER PLOT
ILLUSTRATION 12



Be aware that use of the Hanning Filter, will put a glitch and a spike at the beginning and the end of the time history plot, that will drive the P-P Frequency Deviation number out of spec. Determine the actual P-P Deviation by interpreting the plot. In the example above, Figure 12 the Time History Plot (Frequency Drift) the X scaling is +/- 0.4. Ignoring the artifact at the very beginning and very end of the plot caused by the Hanning Filter the P-P Frequency Deviation is about 0.28.

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